

Review of baseline studies on energy policies and indicators in Malaysia for future sustainable energy development

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ABSTRACT

Malaysia's framework for energy development was established in the early 1970s. Henceforth, many successive policies were introduced as potential resources for electricity generation and utilization. Currently, as a signatory to the United Nations Framework Convention on Climate Change, Malaysia is sparing a number of effort to comply with the policy to meet the challenges of mitigating over-dependence on fossil fuels, reducing carbon levels, and achieving sustainable national development. This paper reviews the baseline studies on electrical energy policies and the measurement indicators used in Malaysia's electric power system. This research involves a comprehensive survey of electrical energy policies in Malaysia that focus on issues pertaining to energy supply, utilization, its environmental impact and considerations, renewable energy (RE) policies, production and consumption, energy efficiency, and feed-in tariffs. Fourteen energy indicators for sustainable development in Malaysia were investigated through the identification of energy policies in significant areas, such as reliability, safety, adequacy and cost-effectiveness of energy supply; increasing energy efficiency; minimizing environmental impact; and enhancing quality of life in terms of social well-being. The policies and the indicators are classified into different sustainable dimensions and summarized in tables along with the corresponding key references. In this study, future energy planning and options, especially in nuclear and RE programs, as well as the conflict between them, are illustrated through the overall performance relative to targets and benchmarks for past and future projections up to the year 2030. This review seeks to examine the past, present, and future policies and indicators to provide a sufficient overview of Malaysian energy policies for optimizing sustainable development. The goal is for this review to lead to increased efforts to accommodate the increasing demand for the management and utilization of RE, promote energy efficiency, and improve performance in achieving sustainable national development.

1. Introduction

In an electric power system, electrical tools are employed to generate, transmit, and distribute electric power. The electric power network that supplies power to homes and industries within a sizable region is called the national grid or the grid in which the generators deliver power to the transmission system. The transmission system then carries power from the generators to the distribution system, i.e., the load centers and the distribution system subsequently supply the power to the load at homes and industries, as shown in Fig. 1 [1,2].

Multiple power sources are connected to most power systems, i.e., external and internal power sources [1]. By contrast, batteries, fuel cells, or photovoltaic cells supply direct current power. The devices

known as turbo generators connected to a rotor that revolves in a magnetic field generate alternating current power. Numerous techniques have been used to spin a turbine's rotor from steam-heated approaches using fossil fuels (such as coal, gas, oil, or nuclear energy), hydro-electric power generation from falling water, and wind power generation [3]. Electric power systems transmit power to the distribution system, i.e., in loads ranging from household appliances to industrial machineries. In general, most loads are rated with a fixed number of phases of voltage and current with a certain frequency and [2]. Most home appliances are typically single-phase or sometimes three-phase equipment operating at 50 Hz, with the voltage depending on national standards.

The conductor carries power from the generators to the load. In

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Nomenclature

AC	Alternating current
CEB	Central Electricity Board
DC	Direct current
EC	Energy Commission (Suruhanjaya Tenaga)
EIA	Energy Information Administration
EPP	Entry Point Projects
EPU	Economic Planning Unit
ETP	Economic Transformation Program
FIT	Feed-in tariff
GHG	Greenhouse gas
GTFS	Green Technology Financing Scheme
HVDC	High voltage direct current
IPPs	Independent Power Producers
KED	Kinta Electrical Distribution
MESITA	Malaysia Electricity Industry Trust Account

MEWC	Ministry of Energy, Water and Communications
MNPC	Malaysia Nuclear Power Corporation
NEB	National Electricity Board
NEPIO	Nuclear Energy Programme Implementing Organization
PRHEP	Perak River Hydro Electric Power Company
PTM	Malaysia Energy Centre (Pusat Tenaga Malaysia)
PWR	Pressurized water reactor
R&D	Research and development
RE	Renewable energy
REPPA	Renewable Energy Power Purchase Agreement
SESB	Sabah Electricity Sdn. Bhd.
SESCO	Sarawak Electricity Supply Company
SIRIM	Standard and Industrial Research Institute of Malaysia
SREP	Small Renewable Energy Programme
TNB	Tenaga Nasional Berhad
toe	Ton of oil equivalent
TSO	Technological Support Organization

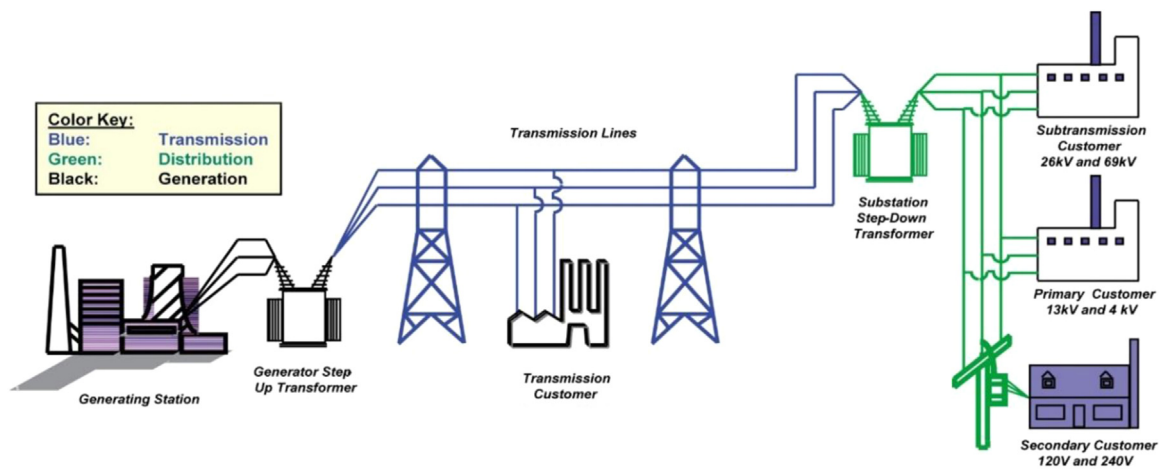


Fig. 1. Basic structure of an electric power system [1,2].

general, conductors are categorized as components of the transmission line that transmits power with high voltages from the generators to the load or the distribution system that supplies power with low voltages from load centers to homes and industries [4]. The conductors of a power system are typically situated either underground or overhead. Overhead conductors are usually constructed with air insulation and sustained on glass, porcelain, or polymer insulators. By contrast, underground conductors have insulation that covers wires with flexible insulation or cross-linked polyethylene [4,5].

Most power system loads are typically linear, i.e., resistive or inductive loads in which the current lags behind the voltage. However, some loads are non-linear. In a power system, reactive power is not measurable but is transmitted between the reactive power source and the load cycle. The transmission of reactive power through generators is recognized as a cost-effective method. If reactive power is provided through capacitors, the capacitors are usually installed near inductive loads to decrease the current load on the power system. To increase the voltage level, power factor correction can be installed at adjacent large loads or the central substation [6]. Reactors are employed to control the voltage on long transmission lines that consume reactive power. In most cases, reactors are placed in a series in a power system to minimize rushes of current flow. Small reactors with capacitors are also placed in a series to limit the rush current associated with switching capacitors. The fault current of a power system can also be limited by connecting series reactors [7].

Power electronics are switching devices that can change the amounts of power fluctuating from a few hundred watts to several

hundred megawatts. The AC-to-DC converter or vice versa is the basic function of power electronic devices [8]. HVDC is a power electronics system used to alternate between AC and DC power for long-distance power transmission. HVDC is reliable and economic, entails low transmission loss, and is environment friendly relative to AC voltage transmission systems. Power systems comprise protective devices, such as fuses, to avoid injury or destruction during failures. The fuse element melts when the current flowing through a fuse exceeds the threshold value. Subsequently, an arc is produced across the resulting gap, which, in turn, interrupts the circuit. The protective relays then sense a fault, initiate a trip, and separate the faulty circuit from the rest of the system in high-powered applications [9].

The current work reviews the baseline studies on energy policies and indicators in Malaysia. A comprehensive survey of Malaysian energy policies and indicators is analyzed for future sustainable energy production, consumption, national development, and related issues. Issues, challenges, and conflicts are highlighted for sustainable energy development in Malaysia through the identification of energy policies for priority areas, such as the adequacy and cost effectiveness of energy supply, improvement of energy efficiency, minimization of environmental impact, and enhancement of quality of life and social well-being.

2. Power systems in Malaysia

Malaysia is located in the southern part of Asia and consists of two separate territories, Peninsular Malaysia and East Malaysia, isolated by

the South China Sea. The country's energy development framework began when petroleum was discovered in the 1970s. Following the Companies Act 1965 [10], Petronas (which stands for Petrolia National Berhad) was established and vested with all the oil and gas resources in Malaysia. Petronas was founded on 17 August 1974 and is wholly owned by the Malaysian government. Resources are managed by Petronas through the Petroleum Development Act 1974 [10]. Other notable policies that influence the country's energy and power industries are the Fifth Fuel Policy 2000, the National Biofuel Policy 2006, and the National Green Technology Policy 2009 [11]. Malaysia entered the renewable and sustainable energy sector through biomass, municipal waste, biogas, mini-hydro, and small-scale solar resources that contributed to clean electricity generation [12,13]. These steps were taken to avoid dependency on fossil and gas fuel reserves.

The power industry in Malaysia has grown significantly in the last decade. This development can be largely attributed to the expansion of the country's industrial and manufacturing sectors. Malaysia's power industry contributes significantly to the nation's economic growth. The primary utility company in Malaysia also enjoys a monopoly. The entire power sector is managed by utility companies. Power sector management involves electricity generation, transmission, and distribution in regions. The leading utilities companies (TNB, SESCO, and SESB) cover the three main regions of Malaysia (Peninsular Malaysia, Sabah, and Sarawak, respectively) [14]. SESB became a subordinate company of TNB. IPPs also contribute to the supply of electricity to consumers through utility companies [14]. The entire sector is regulated through the coordination of several institutions. Such institutions include the EPU, the Ministry of Energy, Green Technology and Water, the EC, and the PTM. These organizations collaborate through planning, R&D, and demonstrations for the energy sector [14].

According to the ETP, transmission and distribution companies are responsible for the following priorities [15]:

- i. Transmission and distribution components, which are the components used in the generation, transmission, and distribution of electricity. These components include transformers, switching apparatus, cable conductor distribution boards, and control panels.
- ii. High value-added production of high voltage transmission and distribution equipment.
- iii. Establishment of a cluster of transmission and distribution vendors in Malaysia. Local companies include Malaysian Transformer Manufacturing, Tenaga Cable Industries, and Tenaga Switchgear.

For high voltage equipment testing, the operation of a high-power testing lab is an important step for the SIRIM. Any transmission and distribution product must be certified through short circuit testing to maintain international standards. Most high voltage lab facilities are in Europe (such as KEMA and CESI) [15]. Any testing lab is required to maintain international testing standards, and therefore, coordination is necessary between the operations of the SIRIM and internationally accredited labs [15]. In 1964, the connection of Bangsar Power Station to

the Connaught Bridge Power Station initialized the National Grid. The interconnection was subsequently extended to Malacca. By 1965, a strategic plan was developed to connect the country's generation plants. Notable plants such as Paka, Batang Padang, Pasir Gudang, Pergau, and Perai were connected through the main energy grid [16]. The Connaught Bridge Power Station located in Klang was the precursor for the National Grid. Other areas, such as the Cameron Highlands Hydro scheme, were also covered. Later, the National Grid was extended into a western network. Lastly, the National Grid loop was established in the 1980s by connecting Kota Bharu [17]. The formation of CEB was completed on 1 September 1949 with the goal of ensuring the proper regulation of the electricity sector [16] (Previously, the Electricity Department was established in 1946). The Board was responsible for three major projects: the Connaught Bridge Power Station, the Cameron Highlands Hydroelectric Project, and the National Grid development project. Thereafter, it became the owner of 34 power stations with a generation capacity of around 39.88 MW. This coverage included a hydroelectric plant with a capacity of 11.1 MW and a steam power station (Bangsar at Ulu Langat) with a total capacity of 26.5 MW [16].

The CEB was under the federation of Malaya. The name CEB was changed to NEB on 22 June 1965 [16]. The Board continued to supply electricity throughout the peninsula region in the 1980s. Moreover, the Board strategically replaced the PRHEP and the subsidiary company KED in 1982 with Huttenbach Ltd. [16]. Mahathir Mohamad, the prime minister of Malaysia then, declared the government's interest in a privatization policy on 4 May 1988 [16]. To implement the government decision, the government passed two legislations that replaced the existing Electricity Act. Hence, the TNB was established under the Electricity Supply Successor Company Act 1990 [16,18]. Currently, transmission substations are interconnected with the National Grid and distribution networks. Transformers are used to reduce the voltage rating to distribution voltage levels. The country's distribution voltage ratings are 33 kV, 22 kV, 11 kV, 6.6 kV, and 400/230 V [18].

3. Energy policies in Malaysia

The Malaysian government defines the country's energy policy, which includes energy generation, supply, and usage. The Department of Electricity and Gas Supply regulates the energy sector. Other players act as energy suppliers, service companies, R&D institutions, and consumers [19]. Petronas and TNB are government-associated firms that play a primary role in Malaysia's energy sector. Other contributors to the policy are government agencies such as the Ministry of Energy, Green Technology and Water, the EC, and the PTM. The policy is based on documents such as the 1974 Petroleum Development Act, 1975 National Petroleum Policy, 1980 National Depletion Policy, 1990 Electricity Supply Act, 1993 Gas Supply Acts, 1994 Electricity Regulations, 1997 Gas Supply Regulation, and the 2001 Energy Commission Act [20]. Three main energy goals have been defined by the Ministry of Energy and Green Technology and Water to guide the establishment of the energy sector. The new energy policy was published in 2010 under

Table 1
Energy policies and objectives in Malaysia from 1975 to 2010.

Policies	Objectives
National Petroleum Policy 1975	• To control the downstream oil and gas industry through the Petroleum Regulations 1974.
National Energy Policy 1979	• To enhance the sufficiency, safety, and cost effectiveness of energy supply; to encourage effective utilization of energy; to reduce negative environmental effects in the energy supply chain.
National Depletion Policy 1980	• To extend the lifetime of Malaysia's oil investments for future security and constancy of oil source.
Four-Fuel Diversification Strategy 1981	• To pursue stable use of oil, gas, hydro, and coal resources.
Five-Fuel Diversification Strategy 2001	• RE involvement as the "fifth fuel" in energy supply combination.
National RE Policy and Action Plan 2009	• To enhance RE influence in the national power generation mix, to facilitate the development of the RE industry, to guarantee rational RE generation prices, to preserve the environment for upcoming generations, and to improve awareness of the role and significance of RE.
New Energy Policy 2010	• To encapsulate all efforts to safeguard financial efficiency and safety of supply and to meet social and environmental aims.

the Tenth Malaysian Plan. The energy policy objectives (supply and utilization) and environmental aims were determined as the main focal areas. The objectives cover five strategic pillars for sustainable development, namely, energy pricing and strategic supply for development, end use energy efficiency, energy governance and regulation, management of change, and affordability. Table 1 details the energy policy activities in Malaysia.

3.1. Policies on energy supply, utilization, and emission

The provision of sufficient, safe, and cost-efficient energy supply was facilitated through the growth of renewable and non-renewable energy sources by using available alternatives and diversifying the delivery sources inside and outside the nation [21]. In terms of supply objectives, the Malaysian government pursued policy initiatives, especially with regard to petroleum and natural gas, by extending the life of local non-renewable sources and diversifying away from oil dependency to comprise other energy sources.

To encourage the effective use of energy and minimize wasteful and non-efficient energy utilization, policies sought to encourage energy consumers and industries to practice efficiency in the generation, transmission, conversion, utilization, and consumption of energy through awareness-raising programs [21–23]. Many initiatives for improved management exerted significant influence on the effective use of energy through incentives such as tariffs. The promotion of efficient methods for energy co-generation from a single source was undertaken through government initiatives [24].

Understanding the effect of energy policies and their indicators is essential to minimize the negative aspects of energy generation, transference, and deployment on the environment. In previous decades, policies related to environmental objectives were limited. However, at present, major project developments are required to conduct environmental assessment prior to development. Emissions, discharges, and noise entail the environmental impacts of energy utilization that must be managed to ensure that processes meet air and emission criteria [25].

3.2. Renewable energy policy

The Malaysian government is currently trying to strengthen energy production from renewable sources. Among such sources, biomass is highlighted as the country has great potential from its palm oil sector. Biomass was planned as the fifth fuel source in the Fuel Diversification Policy of Malaysia [19,21,26]. In 2001, the policy mandated the generation of 5% of electricity from renewable sources by 2005. This requirement meant that the electricity production was set to around 500–600 MW of total production capacity [19]. Hence, numerous efforts were undertaken to fortify the policy. These efforts came in the form of fiscal incentives, allowances in investment taxes, SREP, and so on. As a result, contribution from small renewable electric plants was encouraged to feed the national grid [19,27]. In the SREP project, anyone could sell their generated electricity to TNB for up to 10 MW under an agreement with a 21-year license. The response was positive, with many applicants showing genuine interest. Most of the attention was directed toward electricity generation primarily from biomass and

over 50% from palm oil waste [27]. The number of approved projects for biomass reached 28 in 2005, with the total project installation capacity being 194 MW. Other approved projects included four landfill gas-based schemes with 9 MW capacity and 18 mini hydro-electric plants with 69.9 MW capacity [28]. A summary of the RE policy with the targeted functions is listed in Table 2 [29].

Malaysia's biofuel policy is included in its National Biofuel Policy. To explore the opportunities presented by biofuel-based resources, Yanmar, a Japan-based company that is well known as a global manufacturer of diesel engines, plans to conduct research on the development of palm oil biodiesel [30–33]. The plan includes the development and testing of biodiesel for industrial needs as well as for machines and generators. Numerous related infrastructure has been established in Kota Kinabalu since 2007.

3.3. Policies on production and consumption

Historically, the main sources of Malaysian energy generation are oil and natural gas [34,35]. The country's electricity generation capacity is approximately 20,635 MW. The IPP generation capacity is about 14,777.4 MW. According to the Energy Commission Malaysia, the maximum demand is approximately 16,562 MW, as recorded in 2013 [36]. Fig. 2 and Fig. 3 present historical electricity production and consumption of the Peninsula and Sabah in megawatts from 2010 to 2017 [36–43]. In 2015, the total electricity generation and total demand in Sabah were 1447.8 GWh and 983 MWh, respectively. In the same year, the demand in the Peninsula was 17,370 MW. The sources of electricity production included coal, hydro, and natural gas at rates of 2.9%, 9.5%, and 62.6%, respectively. The remaining 7% was from other forms of fuel [40].

Despite the continuous growth of energy usage, the country has a 33-year reserve of natural gas and 19-year reserve of oil. As the natural sources are being depleted, the government is increasingly considering renewable resources as alternative energy sources. At present, 16% and 84% of total electricity generation come from hydro and thermal sources, respectively [40]. Petronas dominates the oil and gas sector while the EC regulates the entire energy industry in the Peninsula and Sabah. Such regulation is authorized by the terms of the Electricity Commission Act of 2001 [41].

3.4. Policies on energy efficiency and feed-in tariffs

Industrial consumers use approximately 40% of primary energy and 55% of electricity. The total electricity used in Malaysia is 38% of the primary energy sources; this value is equivalent to about 60% of the total energy used in Malaysia. Moreover, the EC of Malaysia has launched various energy efficiency programs [19,44–47].

The government is seeking to strengthen the expansion of renewable generation, especially with biomass as the “fifth fuel” source of its Fuel Diversification Policy. In 2001, the policy aimed to achieve 5% in RE, which is equivalent to 500–600 MW of total installed capacity [46,47]. Many strategies were undertaken to intensify the promotion of the policy, e.g., fiscal incentives, including investment tax allowances and the SREP. Such initiatives also promote linkages between small renewable generation plants and the national grid. In SREP, each project

Table 2
Selected renewable energy policies in Malaysia.

RE Policies	Year	Policy Status	Policy Type	Policy Target
RE Act establishing FIT system	2011	In Force	Economic instruments, Fiscal/financial incentives, Feed-in tariffs/premiums	Solar, Solar photovoltaic, Bioenergy, Biomass for power, Hydropower, Bioenergy
RE Policy and Action Plan	2010	In Force	Research, Development and deployment, Policy support, Institutional creation, Strategic planning	Multiple RE Sources, All
GTFS	2010	In Force	Financial instruments, Fiscal/economic encouragements, Loans	Multiple RE Sources, All



Fig. 2. Peninsula Malaysia's historical electricity production and consumption [42].

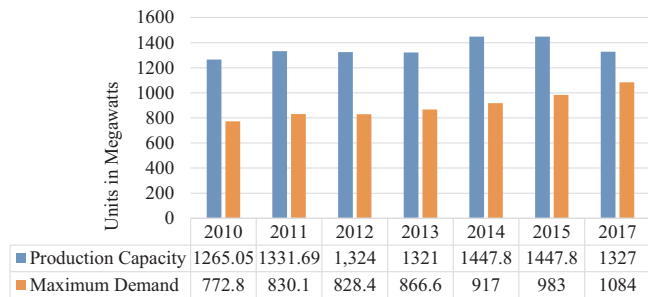


Fig. 3. Sabah historical electricity production and consumption [43].

that can produce up to 10 MW is authorized to sell the generated electricity to TNB under 21-year licensing agreements. Many organizations have applied for this program. Most applications involve biomass, and of these materials, over half are from palm oil waste [38]. In 2005, 28 biomass projects associated with the installation of 194 MW of grid-connected capacity were permitted. Four authorized projects were based on landfill gas and had 9 MW of gas capacity, and 18 mini hydro-electric projects contributed a total of 69.9 MW capacity [38,48,49].

As a way to promote the rural electrification program, the MESITA was successfully established in 1997. It is managed by the MEWC. In MESITA, the main IPPs in Peninsular Malaysia and Sabah contribute about 1% of their annual pre-tax profit for rural electrification as an innovative trust fund. The contributions include promotional activities, direct involvement in RE, energy efficiency projects, and training [36].

3.5. Related energy policy objectives

Green technology is technology that focuses on the improvement and application of equipment, products, and systems to protect environmental resources by minimizing and reducing the negative effects of human actions. This technology is associated with products, equipment, and systems that comply with the following objectives [39]:

- To reduce the deterioration of the environment
- To maintain zero or low GHG release that is not harmful
- To preserve the usage of energy and innate sources
- To inspire the exploitation of renewable resources
- To guarantee that energy supply is sufficient, safe, and economical through renewable and non-renewable sources
- To ensure and stimulate efficient energy utilization
- To reduce the adverse effects of the energy supply chain on the environment
- To extend the lifetime of oil reserves for future safety and sustainability in fuel sources
- To seek balance in the use of coal, gas, oil, and hydro resources
- To promote RE as the fifth energy source
- To employ green technology as the driver to improve the national economy and promote sustainable development

4. Energy indicators in Malaysia

In Malaysia, 14 indicators of energy have been established in the form of sustainable development through the recognition of energy policy priority areas [25]. The priorities identified are as follows.

- Guarantee sufficient and economic efficiency of energy supply
- Improve energy efficiency
- Improve social welfare
- Reduce the negative impact of energy generation on the environment
- Expansion and deployment of RE resources

Energy indicators can be categorized as environmental, economic, and social. Such indicators estimate the priorities of the energy policy. These energy indicators are designed to encourage sustainable development in accordance with Malaysian energy policies. In turn, these

Table 3
Dimensions of sustainable development on Malaysian energy policies.

Sustainable development	Energy priority areas	Energy related topics	Relevant energy indicators
Social	Improving quality of life in terms of social well-being	Accessibility Affordability Disparities	• Rural electrification coverage by region (%) • Share of electricity spending in total household expenditure for different income groups (%) • Share of electricity subsidy received among different income groups (%)
Economic	Ensuring sufficiency and cost effectiveness of energy supply; improving energy efficiency; increasing RE utilization	Overall use Overall productivity Production End use Diversification (Fuel mix) Prices Fuel reserves Climate change Air quality	• Energy use per capita • Energy use per GDP • Rate of self-sufficiency • Share of sectorial energy demand in the total energy consumption • Sectorial energy intensities • Fuel shares in energy and electricity • RE capacity in power supply grid • End-use energy prices by fuel • Reserves-to-production ratio • GHG emissions from energy consumption per unit of GHG • Share of emission loads from the energy sector in the total air pollutant emissions (%)
Environment	Reducing the energy impact on the environment		

priorities were labeled in relation to the dimensions of sustainable development and energy-associated issues. Details of all 14 indicators were established with the essential set of energy indicators for the purpose of sustainable development, energy priority areas, and related energy topics (Table 3) [39].

4.1. Rural electrification coverage by region

The average rural electrification coverage in Malaysia reached 91.5% in 2003 and then rose further to approximately 97.3% in 2017 (Fig. 4). Approximately 4% and 15% of remote rural households in Sarawak and Sabah, respectively, still lack access to electricity. The Malaysian government has set promising objectives to provide the convenience of modern energy facilities, particularly in the rural areas of Sarawak and Sabah [39,45,50]. The Ministry of Rural and Regional Development, as represented in the Ministry of Energy, Green Technology and Water and TNB, undertakes rural electrification programs that cover areas beyond the jurisdiction of local authorities throughout Peninsular Malaysia. The program includes the electrification of indigenous people's settlements, islands, small estates, and remote villages. To solve the electricity supply issue, TNB has agreed to extend their grid to under-served communities; alternatively, the electricity would be supplied using generator sets, solar hybrid systems, and other forms of RE. Accordingly, TNB completed 68 rural electrification projects involving the electrification of nearly 2000 homes in 2013 [51]. To catalyze the rural electrification program, the MEWC has taken the initiative to form a trust fund to which most major IPPs in the Malaysian Peninsula and Sabah contribute about 1% of their annual pre-tax profit to provide rural areas with electricity [52,53].

4.2. Share of electricity in household expenditure for different income groups

The share of electricity payments in the total expenditure for different income groups from 2004/05 to 2016/17 is illustrated in Fig. 5 [39,54–56]. Note that the money spent on electricity was increasing for all income groups during the said periods. This trend was due to the 10% rise in electricity tariff. The rise could also be caused by the value added to living standards, which made the cost of electricity reasonable. Fig. 5 also shows that in all income groups, the overall affordability of electricity increased, which suggests that the poor could improve their standard of living [39,55].

4.3. Share of electricity subsidy received among different income groups

The highest tariff subsidies are applied for the richest group (Fig. 6) [57]. Moreover, the total delivery of tariff subsidies is unbalanced. Electricity tariffs remained almost unchanged from 1998/99 to 2015/16 in most of the lower income groups. Normally, the adjusted tariff is greater than the previous one by approximately 12%. However, users who consume not more than 200 kWh per month or with monthly expenditure below RM 43.60 (April 2008: US\$ 1 = RM 3.19) are unaffected by the new tariff in the new formula [37]. Subsequent reports on the Household Expenditure Survey in 2009 and 2016 demonstrate reasonable tariff subsidy distributions.

4.4. Energy use per capita

The final energy demand in toe per capita and the electricity demand (in MWh) per capita are shown in Fig. 7. Electricity demand per capita increased from 2008 to 2015, thereby forecasting Malaysia's industrial and social development and improved living conditions. A slight decrease in energy demand per capita occurred from 2008 to 2009, reducing the amount from 1.63 toe to 1.46 toe. Afterwards, the value of energy demand went nearly unchanged from 2009 to 2011. However, after 2011, the per capita energy demand increased and

amounted to 1.84 toe in 2017 [58].

4.5. Energy use per GDP (toe/RM million)

In Table 4, the mode of final energy intensity was stable from 1990 to 2017 [51–61]. By contrast, the energy demand per capita was on the rise but declined after 2008 [59–61]. Electricity demand intensity also increased from 1990 to 2017, an indication of the increased electrification of society to accommodate additional home appliances and a broad network. Nevertheless, Malaysia must use electricity efficiently. Primary energy intensity continued at almost an unchanged level from 2000 to 2017, between 118 and 122 toe/RM million, which signifies strong economic development in the manufacturing and service-based economies.

The final energy intensities of the sampled countries are presented in Fig. 8 [62–64]. The economic planning unit of Malaysia has chosen Germany, Denmark, and Sweden as the standards for energy efficiency in the country [46]. Energy intensity in Malaysia is roughly the same as that in Thailand and the USA, but it is higher than those in almost all other countries shown in Fig. 8. This comparison suggests that the economy should be more energy efficient.

4.6. Rate of self-sufficiency

Fig. 9 shows that Malaysia can meet energy demands at present production levels, but its self-sufficiency rate is decreasing. To remedy this, policies seek to improve production and consumption needs to prevent the country from becoming a net energy importer [19,65–68].

4.7. Shares of sectorial energy demand in total energy consumption

The details of major sectorial demands in total energy consumption are shown in Fig. 10. Industrial and transport sectors are the main energy consumers in the country, and the total energy use in these two sectors reached approximately 67% of the entire energy consumption in Malaysia in 2015. The transport sector has dominated the share of total energy consumption since 2000. This situation is due to the increasing annual growth rate of recorded vehicles [69–71]. The sectorial energy demands in agriculture, non-energy sectors, and residential and commercial segments are also rising (Fig. 10) [58,63].

4.8. Sectorial energy intensities

Fig. 11 displays the trend of the final energy intensities between 2005 and 2013. The primary intensity of electricity consumption continued to decline from 2005 to 2011, but in 2012, the primary energy intensity increased by 3.4% compared with the previous year, and such change was attributed mostly to the industrial sectors [37]. A slight decrease in the final energy intensity amounting to 53.42 toe occurred in 2010, and the value declined to 51.96 in 2015. This stabilized energy intensity suggests that the energy demand in Malaysia has been rising

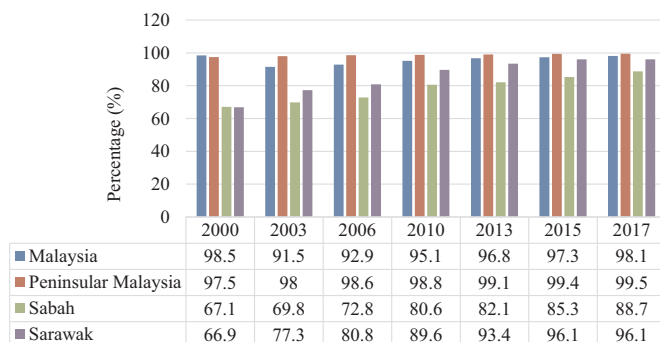


Fig. 4. Rural electrification coverage by region, data and projections (%) [53].

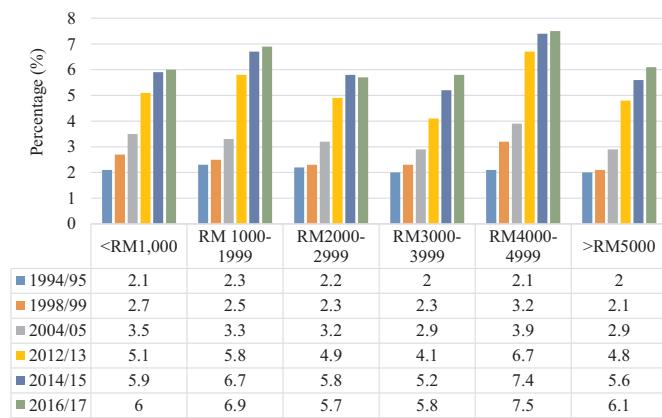


Fig. 5. The share of electricity spending in overall household expenditure for different income groups (%) [56].

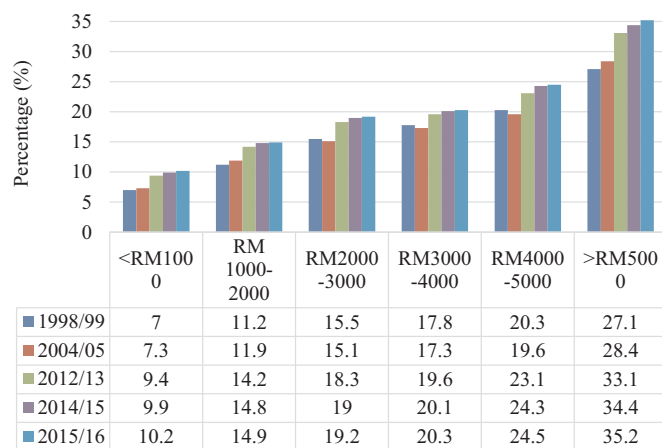


Fig. 6. Electricity subsidy received among different income groups [57].

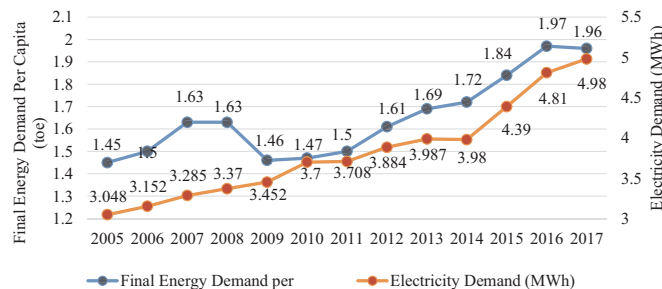


Fig. 7. Electricity and energy demand per capita [58].

with its economic growth while the final energy intensity has improved since 2005.

4.9. Fuel shares in energy and electricity

Crude oil is currently the dominant conventional fossil fuel in energy supply, followed by natural gas. Fig. 12 shows that these fuels represent more than 70% of the entire energy supply [45,72–74]. This finding indicates that Malaysia is highly dependent on petroleum. However, in line with the Eighth Malaysia Plan (2005–2011) [73], usage of coke and coal as supply sources for energy have been enhanced, and this development, in turn, shows a decrease in dependency on natural gas and crude oil.

Although the main energy consumed as of 2014 involved petroleum products, petroleum product shares in total energy consumption have

Table 4

Historical data for energy intensity and demand [62].

Energy indicators	Primary Energy Intensity (toe/GDP (RM Million))	Final Energy Intensity (toe/GDP (RM Million))	Final Energy Demand per Capita (toe Per Capita)	Demand Intensity (GWh/GDP (RM Million))
1990	99	61	0.73	0.092
1995	99	65	1.07	0.115
2000	118	69	1.26	0.142
2005	122	70	1.45	0.148
2006	118	70	1.5	0.147
2007	119	73	1.63	0.146
2008	118	70	1.63	0.145
2009	118	65	1.46	0.153
2010	114	61	1.47	0.155
2011	112	61	1.5	0.151
2012	116	64	1.48	0.152
2013	115	65	1.52	0.155
2014	118	67	1.56	0.156
2015	120	70	1.54	0.158
2016	125	69	1.57	0.159
2017	127	71	1.55	0.161

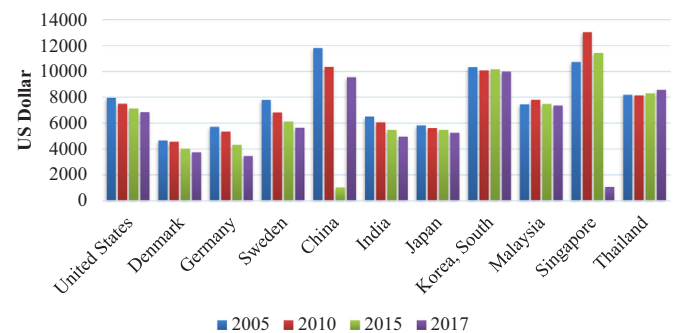


Fig. 8. Final energy intensities for selected countries [64].

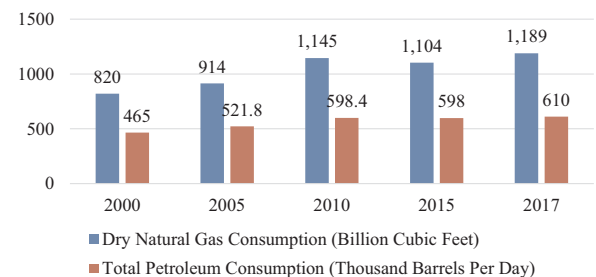


Fig. 9. The rate of energy self-sufficiency [63].

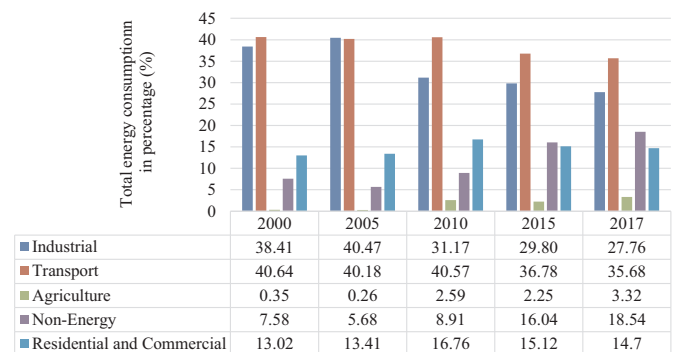


Fig. 10. The share of sectoral energy demand in total energy consumption [58,63].

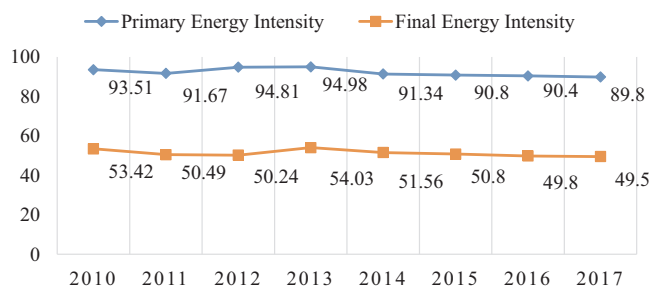


Fig. 11. Final energy intensity (toe/RM Million) and primary energy intensity (GWh/RM Million) from 1990 to 2012 [63].

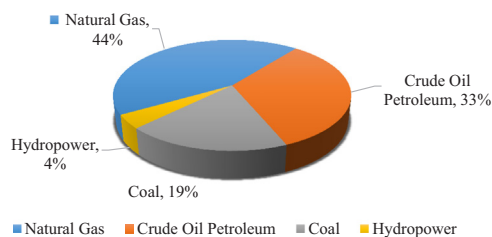


Fig. 12. Share of total primary energy supply in Malaysia [74].

been increased in accordance with the national depletion policy and fuel diversification policy (Fig. 13) [5,63,75,76].

In the Seventh Malaysia Plan (1996–2000), the mix fuel for generation was expanded through reduced dependency on oil and increased use of natural gas and hydropower. Struggles toward diversification remained throughout the Eighth Malaysia Plan (2001–2005), with the share of coal as an electricity generating source increasing and the share of both natural gas and oil decreasing [77]. This outcome illustrates the success of advanced and energy policies in diversifying the mix generation. However, on 31 December 2012, the installed capacity in the Peninsula powered primarily by natural gas and coal and partly by hydroelectric plants reached 21,749 MW [49]. Fig. 14 shows that the electric power generation mix for Peninsular Malaysia is due to the approved Generation Development Plan [78]. Clearly, coal power generation has been stimulated, and gas power generation has decreased because of the policy. Moreover, a reasonable amount of generated power can be expected from the Sarawak interconnection [49].

4.10. RE capacity in the power supply grid

In accordance with the policy of supporting the deployment of RE sources, 350 MW produced from RE was agreed upon as a goal to be accomplished by 2010 [46]. As of 2006, a total of 12 MW had been produced from RE, including 10 MW from empty fruit bunches and 2 MW from biogas. This Fig. (12 MW) accounts for only 3.4% of the 2010 target [79].

4.11. End-use energy prices by fuel

Prices of energy with and without subsidies in Malaysia represent a significant challenge for the country. In general, the energy prices in Peninsular Malaysia, Sarawak, and Sabah reached the average, although those prices were adjusted in March 2006. The unsubsidized prices are greater than the retail prices. The government subsidizes approximately half of the unsubsidized price of LPG as part of the policy for endorsing this clean sustainable fuel [80]. Regarding the electricity tariff schedule, the government and TNB rate a new tariff under the domestic and commercial categories that have been in operation since 1 January 2017 (Table 5). The new tariff replaces the earlier tariff table, and this replacement was put in effect on 1 June 2011. The details can be found in [54,81].

4.12. Reserves-to-production ratio

As shown in Fig. 15, the natural gas reserves have dropped since 2000 [63,72,82]. Consequently, the proper organization of recognized energy assets is a contentious matter in the national sustainable energy programs in Malaysia [35] as natural gas and crude oil are clearly decreasing (Fig. 15).

4.13. GHG emissions from energy consumption per unit of GDP

The latest statistics for three leading GHG emissions from energy consumption per GDP from 2000 to 2017 is shown in Fig. 16 [19,83]. The total CO₂ emissions from the consumption of energy sources per dollar of GDP (carbon intensity) from the USA, Malaysia, and several other countries are presented in Fig. 16. Statistics on CO₂ emissions from energy consumption of natural gas, petroleum, coal, and natural gas burning are accessible from the USA EIA energy statistics database. Note that China is the highest contributor of CO₂ emissions, followed by India, Indonesia, Thailand, and Malaysia [37]. CO₂ emission in Malaysia is higher than that in Japan, Korea, and some European countries.

4.14. Shares of emission load from energy sector in air pollutant emissions (%)

Fig. 17 shows that CO₂ contaminant emissions generally come from energy burning activities, particularly from the transport sector [84,85]. CO₂ emissions from petroleum are understood to be greater than those from other sources. The capacities of CO₂ emissions from natural gas, coal, and petroleum in 2011 increased by 25%, 13%, and 10%, respectively, compared with the figures from 2000 [37].

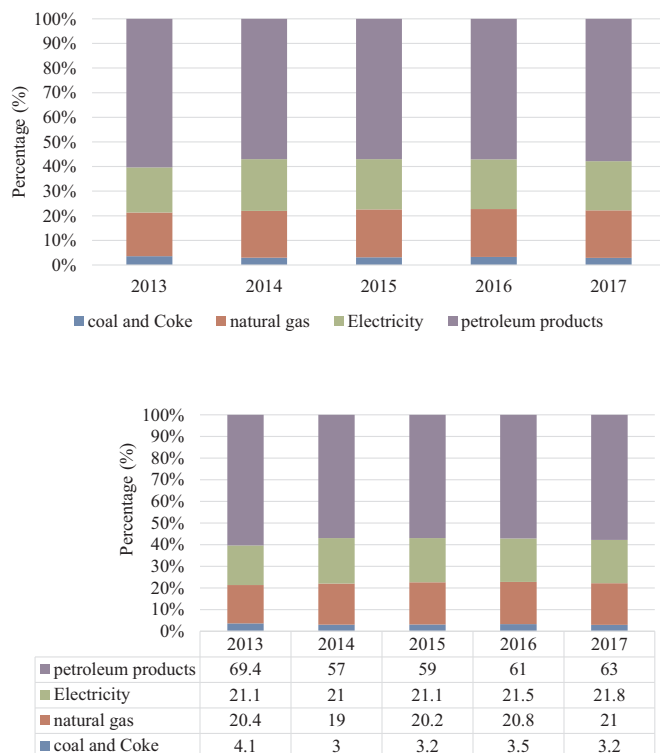


Fig. 13. Fuel shares in total energy consumption [63,76].

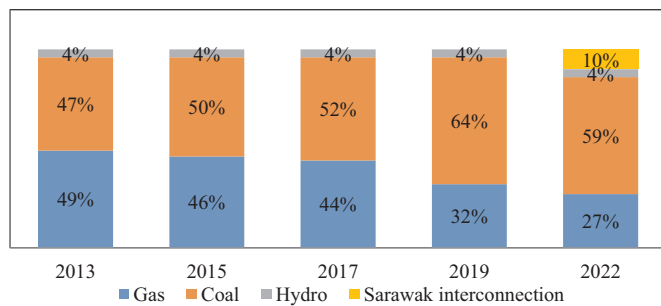


Fig. 14. Generation mix for peninsula Malaysia based on the approved generation development plan [78].

5. Future energy planning and alternatives in Malaysia

5.1. Nuclear power program

Nuclear power plants are possible alternatives for the Malaysian Government as they implement the building of nuclear power plants or shift to other plants. Recent activities drew attention to detailed studies regarding some considerations and toward identifying issues such as assessing the present countrywide capability levels and the state of preparedness in relation to the progress of a nuclear plant system. Moreover, 1 out of 131 operating EPPs were established by the government through an ETP. Some of the major activities in nuclear power plants are run by the MNPC with the cooperation of NEPIO and TSO, although the nuclear timeline is unclear [21]. The authentic choice for the development of projects for nuclear power programs could be ascertained by the national government after considering the details of existing studies.

One may ask whether Peninsular Malaysia needs to develop nuclear plants despite the large gap in the reserve margin. At present, the peak demand monitored in 2016 was 18,338 MW (Table 6) [51]. This figure translates into a 40% reserve margin [41,59]. This level of reserves should be used to maximize profits. According to an annual load growth and suspension of present capacity to meet economic needs, the reserve margin should be reduced. Demand for electricity is expected to rise by 3–5% annually from 2010 until 2030 in Peninsular Malaysia alone. By 2030, peak demand is estimated at 24,770 MW with a growth rate of 1.4% per annum [19,46,68,77]. Given such statistics, Peninsular Malaysia does not appear to need the new plant scheduled for 2018. The reserve margin will naturally shrink over time without new plants to add capacity given the great demand for electricity and the retirement of existing plants. By 2018, the reserve should be an estimated 20% [19,68,77]. However, Fig. 18 shows obvious increasing demand and declining reserve margin without considering the introduction of new loads to the system. In the case peak demand of 15,826 MW, which was monitored on June 2012, the total generation was 108,443 GWh from 1 January to 31 December 2012, indicating a rise of 2.6% compared with

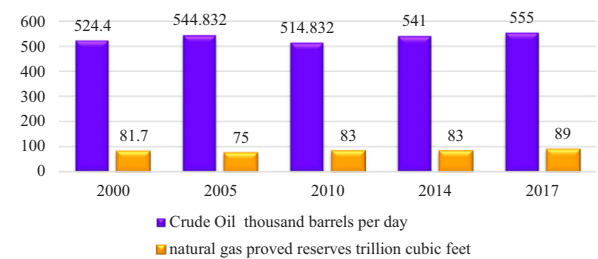


Fig. 15. Proved reserves of natural gas and crude oil [63].

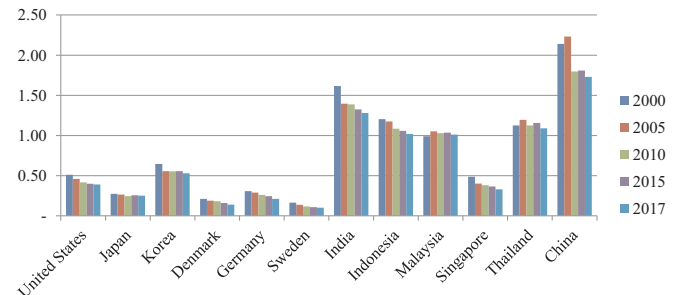


Fig. 16. CO₂ emissions from the energy consumption per dollar of GDP for a number of countries (Tonnes/'000 2000 USD) [83].

the value in the earlier year. The main consumer was the industrial sector in Peninsular Malaysia, contributions to 43.6% of the entire consumption in 2012. Fig. 18 shows the forecasted peak demand and reserve margin projected up to 2030, in which the peak demand grows proportionately annually while the reserve margins decrease sharply [77].

5.2. Renewable energy program

The potential for hydro energy in Peninsular Malaysia is lower than that in Sarawak and Sabah. The share of hydropower in the Peninsula is projected to rise from 5% in 2008 to 35% in 2030 [86]. This figure is considered minimal in relation to the high electricity demands in the Peninsula. In addition, the residual potential in Peninsula is at a peak with inadequate energy. An additional issue with hydro energy is that it requires a sizeable area, resulting in the possible uprooting of native inhabitants from floating areas. This requirement may cause costs to rise exponentially.

Malaysia seeks to promote RE as a main resource for power generation by introducing the Five-Fuel Policy. At present, RE has been developed in Peninsular Malaysia under the SREP program. SREP is a mechanism based on a ready-buyer-and ready-seller system developed under the REPPA. This operation began between SREP and TNB [79,87]. Thus far, 59 applications have been received (Table 7). Only 29% of the applications have been approved by REPPA, with the overall

Table 5
TNB tariff rates for domestic and low voltage commercial entities [54,81].

Tariff Category	Unit	New Rates (1 January 2014)
1. Tariff A – Domestic Tariff		
For the first 200 kWh (1–200 kWh) per month	sen/kWh	21.80
For the next 100 kWh (201–300 kWh) per month	sen/kWh	33.40
For the next 300 kWh (301–600 kWh) per month	sen/kWh	51.60
For the next 300 kWh (601–900 kWh) per month	sen/kWh	54.60
For the next kWh (901 kWh onwards) per month	sen/kWh	57.10
The minimum monthly charge is	RM	3.00
2. Tariff B – Low Voltage Commercial Tariff		
For the first 200 kWh (1–200 kWh) per month	sen/kWh	43.50
For the next kWh (201 kWh onwards) per month	sen/kWh	50.90
The minimum monthly charge is	RM	7.20

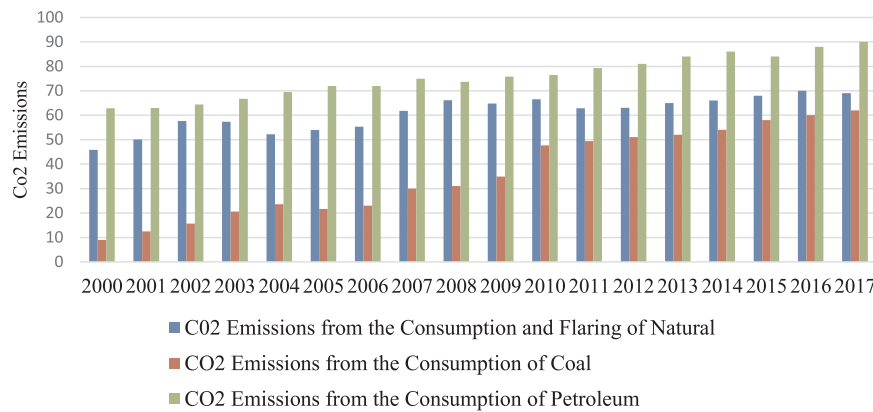


Fig. 17. CO₂ emissions from the consumption of natural gas, coal, and petroleum (million metric tons) [85].

Table 6

Long-term load forecast as approved by the planning and implementation committee for electricity supply and tariff in 2012.

Year	Peak Demand MW	Growth%	Year	Peak Demand MW	Growth%
2003	11,329	5.1%	2017	18,926	3.2%
2004	12,023	6.1%	2018	19,558	3.3%
2005	12,493	3.9%	2019	20,149	3.0%
2006	12,990	4.0%	2020	20,847	3.5%
2007	13,620	4.8%	2021	21,456	2.9%
2008	14,007	2.8%	2022	21,908	2.1%
2009	14,245	1.7%	2023	22,067	0.7%
2010	15,072	5.8%	2024	22,490	1.9%
2011	15,476	2.7%	2025	22,900	1.8%
2012	15,826	2.3%	2026	23,298	1.7%
2013	16,562	4.6%	2027	23,685	1.7%
2014	17,131	3.6%	2028	24,058	1.6%
2015	17,671	3.2%	2029	24,420	1.5%
2016	18,338	3.8%	2030	24,770	1.4%

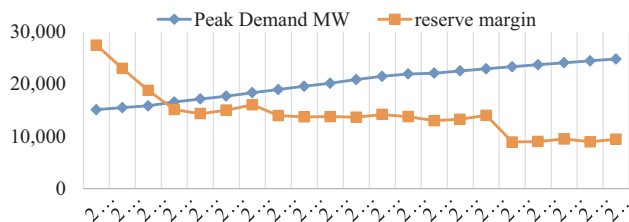


Fig. 18. Demand forecast and reserve margin curve [77].

Table 7

Current status of RE power generation through the RE power purchase agreement.

No.	Item	No.	Capacity (MW)
1	April 2010-REPPA signed	17	88.15
	Project commissioned (COD)	6	24.7
	REPPA signed	8	41.45
	REPPA terminated	3	22
2	Project not signed	14	108.9
3	Project not yet approved by SCORE	4	30
4	Project rejected by EC	7	37
Total applications		59	264.05

capacity reaching 88.15 MW [87]. Only six plants are currently operational with an entire capacity of 24.7 MW. This figure means that RE has not been developed significantly. The slow development of RE may result in a lack of healthy commercial mechanisms to assist in the growth of RE. However, the FIT scheme was presented by the

government under the RE Act and Action Plan in 2012. FIT involves buying power from RE developers at best rates [88,89]. The expansion of RE is expected to thrive. Nevertheless, the government must still seriously consider nuclear energy given the intermittency of RE, the cost of technology, and distant location of some RE sources. The development of RE should last, and with upcoming technological development, further assistance for RE could be expected. However, this development might not transpire in the present or near future. Therefore, the government must examine alternatives, such as nuclear resources.

5.3. Future energy sources

Nuclear plants are crucial for electrification in Peninsular Malaysia as they will enhance the reliance of the mix generation on different energy resources. At present, Peninsular Malaysia depends on gas. In 2008/2009, 65%, 29%, and 6% of electricity generation were derived from gas, coal, and hydro energy [88]. If this trend continues, then most of Malaysia's fuel sources, including gas, will be imported. Fossil fuel will be replaced on a real-time basis. In that scenario, any trouble on the supply side could pose a serious threat to meeting the desired demand [90].

Nuclear power generation is unlike any other technology. It involves fuel loaded once in an 18–24 month cycle. The long fuel cycle allows for planning, improves confidence, and reduces supply security threats. By contrast, natural gas for the future could entail imported fuel. Petronas stated that Malaysia's natural gas is decreasing [35,90]. Currently, natural gas is derived from local fields in addition to exports from West Natuna Island and from joint development areas. However, most of these local sources will soon be depleted, indicating that Peninsular Malaysia cannot rely on gas alone for electricity.

Now, electrification using coal is completely reliant on import from countries such as South Africa, Australia, and Indonesia. Possible interruption in supply is a serious threat to the nation. Countries exporting coal could suddenly change their policies in the upcoming years because of their own consumption and increasing demand. Add to these considerations the intense competition from countries, such as India and China, for coal given the rapid growth of such nations. Similarly, Japan, Korea, and Taiwan are also competing for coal. This circumstance will certainly cause the price to increase in the future. Politics and logistics are other concerns arising from the generation of electricity from coal sources. Difficulties may arise because of bad weather or labor regulations. These situations place great risk on energy security if the country relies on a single source for energy generation.

5.4. Conflict between nuclear and renewable energies

The progress of RE as the fifth fuel will not be affected by the

development of nuclear power. The early plans of Malaysia in 2006–2010, i.e., the Ninth Malaysian Plan, reveal that the target of RE was 300 MW. However, RE development is managed by SREP and directed by the Suruhanjaya Tenaga official energy commission [91,92]. That target could not be achieved because of the sluggish implementation of RE. Nevertheless, in 2012, Malaysia became highly committed to developing RE, given the implementation of the RE Act and Action Plan.

Nuclear energy is considered clean energy. However, debates continue about whether it qualifies as RE. Comparing RE and nuclear plants is not a fair practice. Wind, solar, or biomass sources could generate clean and infinite energy without actual fuels but not in a manner that is similar to the generation of energy from nuclear sources.

Normally, a nuclear power plant generates continuous power at constant output and would generally run at 80% of its capacity or more [93,94]. Output from nuclear plants does not need to be adjusted to the daily demand because of complications of component designs. The plants will only be shut down when it is time to fill the fuel. Different types of reactors, such as the PWR, are available. The fuel loading for this type of reactor is prepared once every 15–18 months and takes one month to accomplish. Until the next fuel filling, these types of plants operate at maximum capacity. Besides filling the fuel, major assessments and inspections of plant components are required. The characteristics of nuclear plants make them appropriate for Peninsular Malaysia because they supply the base load requirements. At present, the minimum demand stands at approximately 10,000 MW. This minimum demand, which include gas and coal, must be served by base load plants. In that case, nuclear plants will be among the essential plants operating as base load supply [95–98].

Employing RE to meet the load demand is extremely difficult as challenges remain in terms of small capacity generation. For example, a station for a PV solar farm has a production capability of approximately 10–60 MW, with the largest PV solar plant installed in Spain producing 60 MW. By contrast, nuclear plants can produce 600–1000 MW. As such, an enormous difference exists between the energy produced by RE and by nuclear plants, especially in relation to the base load supply. RE operates on a small scale and can thus only be considered as a supplement for addressing minor demands or aiding remote areas. Therefore, until now, trusting RE generation for total power is impossible [40,80,90].

Furthermore, many concerns remain over the intermittency of RE. Sunlight radiation in Peninsular Malaysia (which is located in the equatorial region) is approximately 4500 kWh/m² on average. Malaysia essentially receives four to six hours of sunshine daily on average [38,99,100]. Although solar energy provides a promising future for the country, it requires high capital investment and a large area to generate a reasonable amount of electricity [36,40,45].

As regards wind energy, implementation and possibilities are extremely limited in Peninsular Malaysia. Numerous research have been conducted by different universities and parties on the capability of exploiting wind energy in several areas in the Peninsula [19,67,101–103]. However, results indicate the low wind potential in the area.

Other RE sources, including biomass, solid waste, and biogas plants, are undergoing serious development. To date, 88 MW of RE projects have agreed upon by SREP, with an expected 40.35 MW produced from biogas and biomass sources. Compared with solar and wind sources, these sources do not face intermittency problems. They can produce electricity at any time. However, some of these sources use “dirty” technology because of the need to burn the input sources to produce electricity.

One of the main concerns facing RE development is the sizable capital investment. This cost may be offset via the FIT mechanism initialized along with the RE Act and Action Plan in 2012 [46,104]. FITs are officially assured payments for electricity service providers generated by green technologies, including solar, wind, biomass, or small

hydro power plants connected to national electricity networks. Mechanisms like this have been employed in countries such as the USA, Spain, and Germany, and they have successfully encouraged the growth of clean energy.

In conclusion, relative to RE, nuclear plants are essential for serving the bulky base load supply given its continuous production and output. By contrast, RE cannot provide a secure source of energy. Even though its development is undoubtedly robust in terms of providing absolutely clean energy that could protect the environment, fuel diversification is essential to avoid potential disruptions in energy supply and cope with the ongoing development of green technology [91,92].

6. Challenges and future perspective view of energy policy in Malaysia

The major challenges that could arise in the Malaysian power sector are as follows.

6.1. Energy policy

As a rapidly developing country, Malaysia presents a rapidly increasing energy consumption, leading to pressures on its reserved natural sources for forthcoming demand. These issues require the dependability and safety of energy supply and the expansion of different energy sources. The diversification of energy ensures that the country is not reliant on a single energy source. Such approach is also significant for minimizing the negative impact of current energy sources on the environment. Conversely, green energy resources are extremely costly. Malaysia is suffering from economic issues, and this situation will be a key challenge to its investment in sustainable energy sources. In this case, the government can encourage the private sector to become involved in improving the energy sector. Such participation depends on the plans and policies that motivate private enterprises to assist the government. An awareness program encourages the public to save electricity. The Malaysian government must search for new solutions contrary to other extensively used technologies. Notably, investment in sustainable energy sources in 2008 was defined by the global recession. Therefore, the country's policy must be optimized such that recession can be avoided while investing in green technology. The Malaysian government has recently adopted the National Green Technology Policy that ensures the long-term sustainability, reliability, and security of energy supply for continuous development and growth. The government is also considering adopting nuclear technology to meet the growing electricity demand. However, after several incidents with Japan's nuclear power plant, the Malaysian public are concerned about the possible consequences of its implementation. Hence, the situation must be carefully managed by creating widespread policies. There is, therefore, in future it is very important to carefully manage the situation by creating widespread policies.

6.2. High voltage transmission line issues

Peninsular Malaysia will surely face an energy crisis given the depletion of the natural sources for electricity, which is expected to be completely exhausted by 2030. The electricity generated from Sarawak and Sabah must then be transmitted to Peninsular Malaysia. Given the distance between the areas, an undersea transmission line is required to supply electric power to Peninsular Malaysia. At present, to send 2400 MW of generated electricity from the Bakun Dam hydro power plant, the transmission line would require approximately 730 km HVDC and 670 km submarine undersea power cable. However, enormous potential for producing electricity is noted in the hydroelectric plants in the rivers of Sarawak. The Malaysian government is pursuing this project, but connecting new transmission lines for additional power transmission to Peninsular Malaysia is a considerable challenge. The installation cost of the transmission line is approximately US\$ 3.5

billion, and that figure is estimated to increase the number of parallel transmission lines to guarantee backup transmission and additional power transmission. The total cost will increase with the installation of each additional transmission line. In addition, Association of Southeast Asian Nations (ASEAN) including Malaysia has planned to develop ASEAN grid for sustainable electricity export-import practices. However, there are major barriers and technical challenges for establishing an ASEAN power grid. Therefore, in future, it need develop policies and techniques to overcome the limitations associated with the establishment of the ASEAN power grid, as well as future research direction in enhancing the utilization of Malaysian power grid.

6.3. Renewable energy projects

A five-fuel diversification strategy energy mix was approved by Malaysia in 1999. Oil, natural gas, coal, hydro, and RE are considered as the five main energy sources. As an alternative source of future energy and part of green energy, RE projects are encouraged by the government. Only RE is environmentally friendly, abundant, and untapped. Therefore, the government promotes RE. However, the percentage of RE implementation is low because of its high installation costs. RE is generated on a small-scale basis, although Malaysia has abundant RE resources. The government exerted effort to introduce the SREP Program in 2001, covering biomass, biogas, landfill waste, and mini-hydro plants. Recently, solar PV and wind have become areas of focus to increase electricity generation. In the Tenth Malaysian Plan, the target amount of electricity generated from RE is set at 5.5% of the total electricity generation, which was 98 MW in 2015. Meeting this target is certainly a challenge. To overcome challenges, under the New Economic Policy (NEP) and government-linked companies' involvement a free-market economic policy and blue ocean strategies should be deployed to encourage the growth of RE inclusion in the system. Accordingly, the Ministry of Energy, Green Technology and Water, Malaysia is developing the Renewable Energy Transition Roadmap 2050 as a successor to the incumbent National Renewable Energy Policy and Action Plan.

6.4. HVDC line construction

As HVDC is the preferred choice for renewable generation, the construction of HVDC is a major challenge for Malaysia. In transmitting huge amounts of power with minimum losses, HVDC rather than HVAC lines should be adopted. Few HVDC projects are extant in Malaysia. To ensure maximum area coverage by electrification and generation from renewable sources, establishing the infrastructure to facilitate power transfer and extreme generation from RE is essential. Safeguarding the path of electricity flow is also a chief concern. Controllability, efficiency of power transmission, and HVDC technology are now preferred. Hence, HVDC is a key technology in overcoming a significant issue with RE generation, such as with wind, solar and hydro resources, as these resources are not often located close to the population centers that need them. However, initial investment for HVDC is more expensive than that for HVAC. According to the ASEAN HVDC transmission planning, peninsular Malaysia and Sumatera HVDC interconnection development is in progress under power exchange agreement (PEA) and interconnection agreement (IA) which will operate on commercial basis instead of strategic basis.

6.5. Greenhouse emissions

In Malaysia, natural gas and coal are the main resources responsible for emitting GHG emissions in the energy mix, followed by hydro energy sources. Oil is rapidly depleting, causing it to no longer be recognized as a feasible source for generating electricity. Nowadays, it is used only as backup supply for emergencies. The toxic emissions from the burning of fossil fuels that cause climate concerns also affect

Malaysia. Fossil fuel burning is a vital issue for power development projects. Total CO₂ emission is increasing, and an estimation in 2010 indicates a value of 216804, which is 0.69% of total global emissions [83]. Therefore, the usage of fossil fuels will significantly contribute to the emission of GHG from their combustion, thereby exacerbating the climate changes issue significantly. The Malaysian government must find alternative sources of development and move up the value chain. Accordingly, the Malaysia is on track to reduce carbon emissions by 40% within coming few years for a cleaner environment for future generations and 45% by 2030, and be fully carbon neutral by 2050.

7. Conclusion and recommendation

The main contributions of this review are to highlight Malaysian energy policies and indicators to manage increasing energy demand, utilization of RE, promoting energy efficiency and improving environmental performance in achieving sustainable development. Several energy policies have been discussed including policies on energy supply, utilization and emission, renewable energy, production, consumption, and energy efficiency and feed-in tariffs. A total of 14 energy indicators have been comprehensively explained and categorized as environmental, economic and social impacts on energy considerations to improve energy efficiency, guarantee sufficient energy supply, expand the RE sources and reduce the GHG emissions, respectively. In addition, the review has addressed future energy planning and options in Malaysia including the nuclear and renewable power program. Furthermore, the review also highlights the various issues and challenges for introducing future policy implementation. Finally, the review also provides some selective suggestions for further improvement in achieving sustainable development in Malaysia.

- i. Malaysia's extreme dependence on exporting natural gas and oil to sustain its economic growth will be short-lived and therefore, it is an urgent need to switches conventional power to sustainable resources. The government should promote RE resources through various incentive plans to ensure reliability and security of energy supply as well as to achieve long-term sustainability.
- ii. The electricity tariff rate should require more reasonable tariff subsidies for distribution among different income groups.
- iii. Various awareness-raising programs need to be organized to alert the consumers and industry for the efficient utilization and consumption of energy.
- iv. The government should introduce effective plans and policies to motivate private enterprise to become involved in improving the energy sector.
- v. The government of Malaysia needs more attention on rural electrification program
- vi. The Malaysian government should take effective measures to reduce CO₂ emission and should focus on clean development mechanism implementation.
- vii. The Malaysian government must decide whether to invest millions in green technology or nuclear plants. Nuclear energy is environmentally friendly when under control but can pose serious threats if unstable.

These recommendations would be a significant contribution towards the achievement of future energy security and sustainability in Malaysia through the execution of various effective policies.

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